

# Mapping the Milky Way

Y. Xu

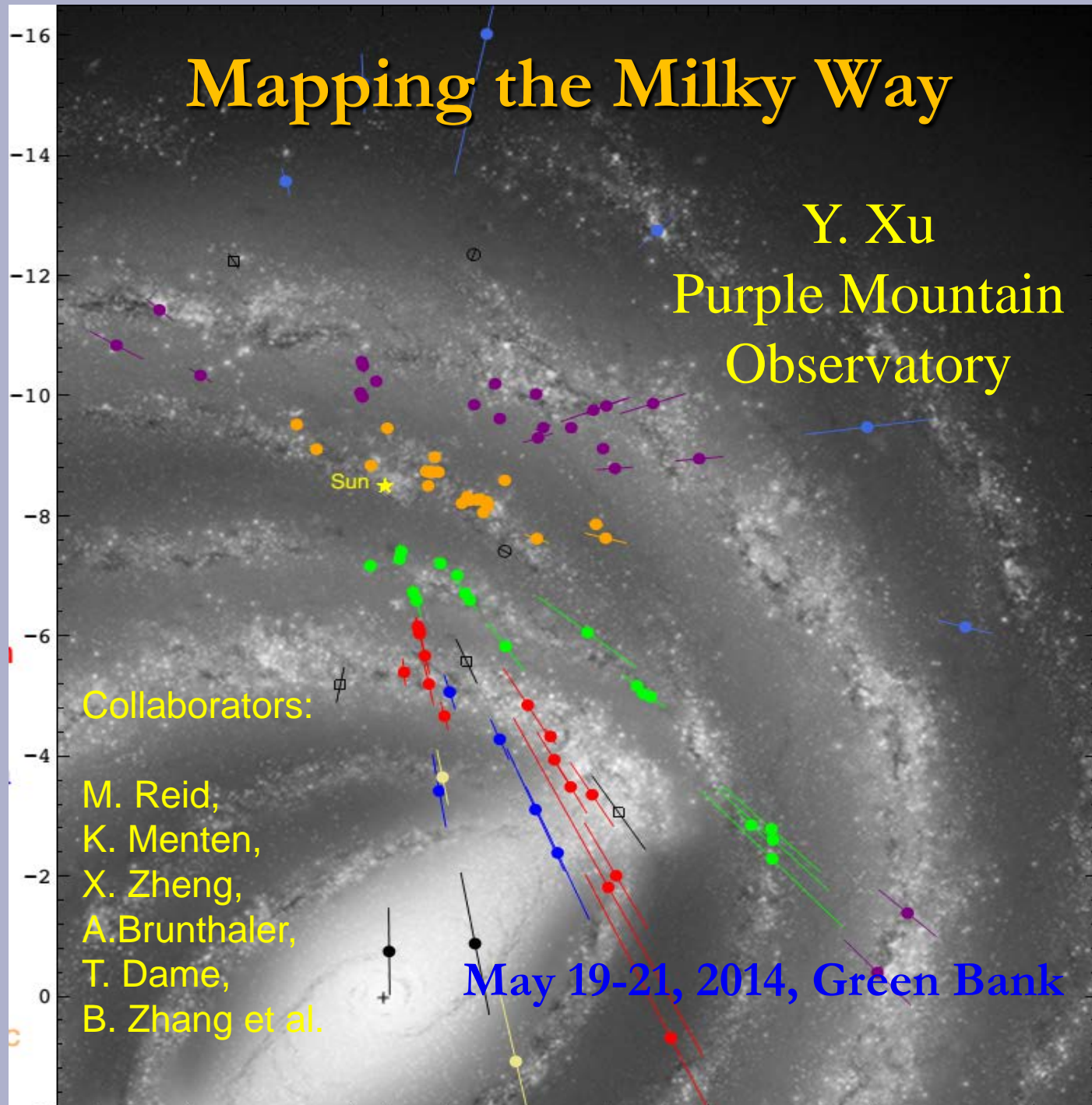
Purple Mountain  
Observatory

Sun ★

Collaborators:

M. Reid,  
K. Menten,  
X. Zheng,  
A. Brunthaler,  
T. Dame,  
B. Zhang et al.

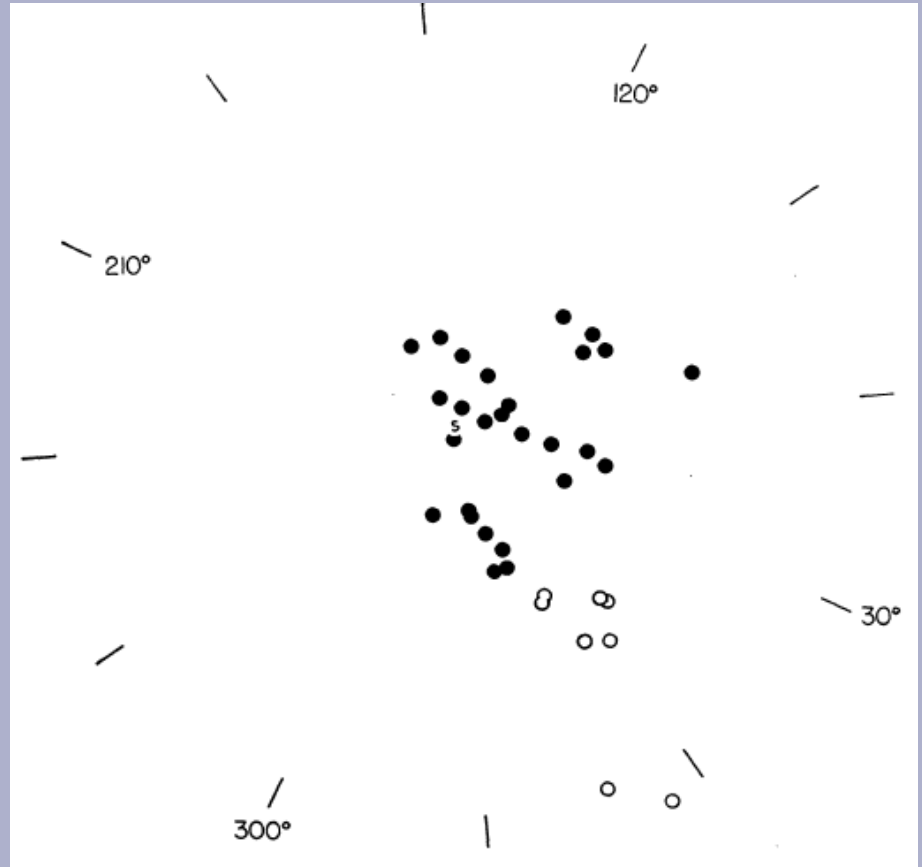
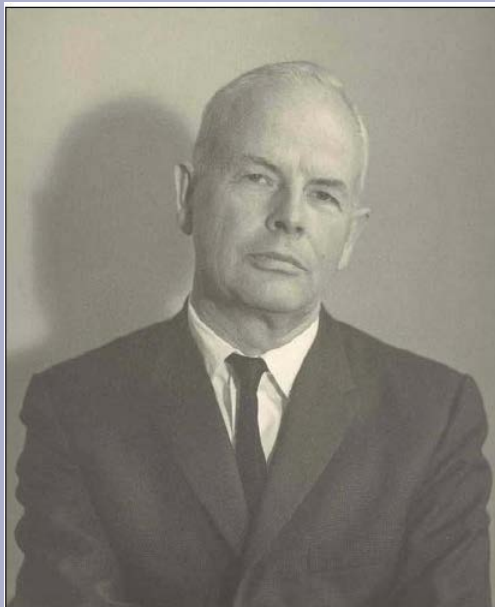
May 19-21, 2014, Green Bank



# The First Evidence for Spiral Structure of MW

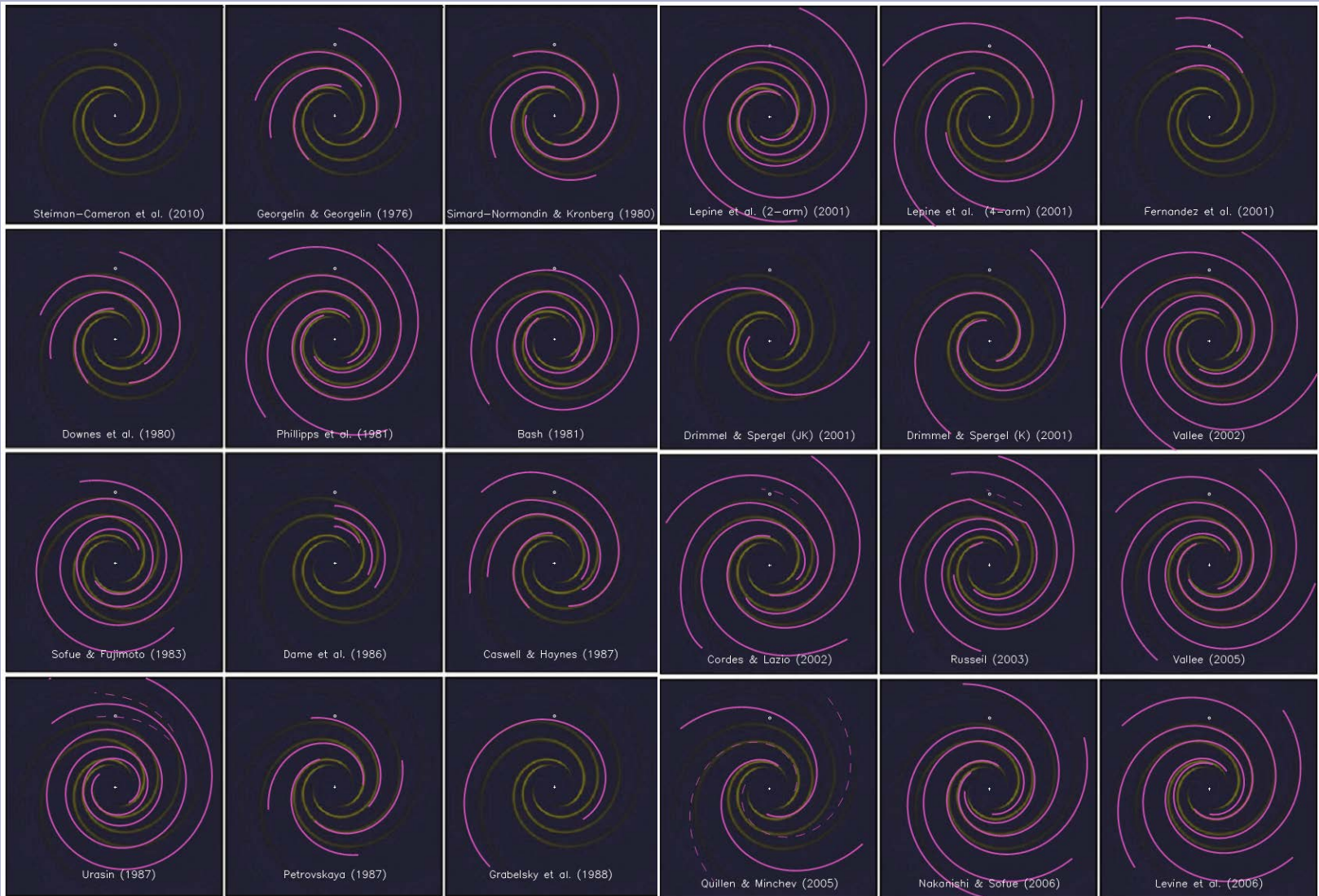


Inside the Milky Way, edge-on,



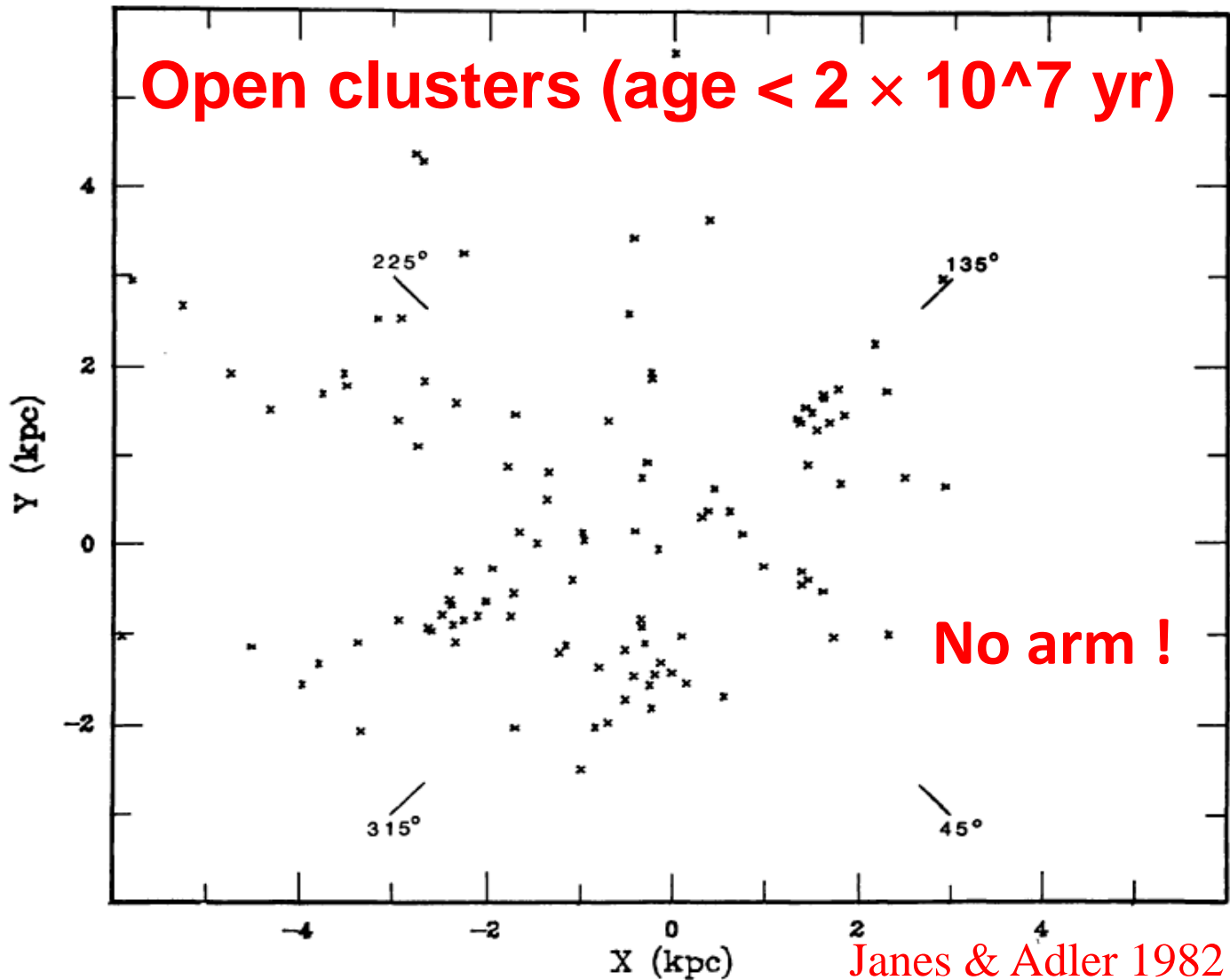
Morgan et al. 1952, 1953

# Models

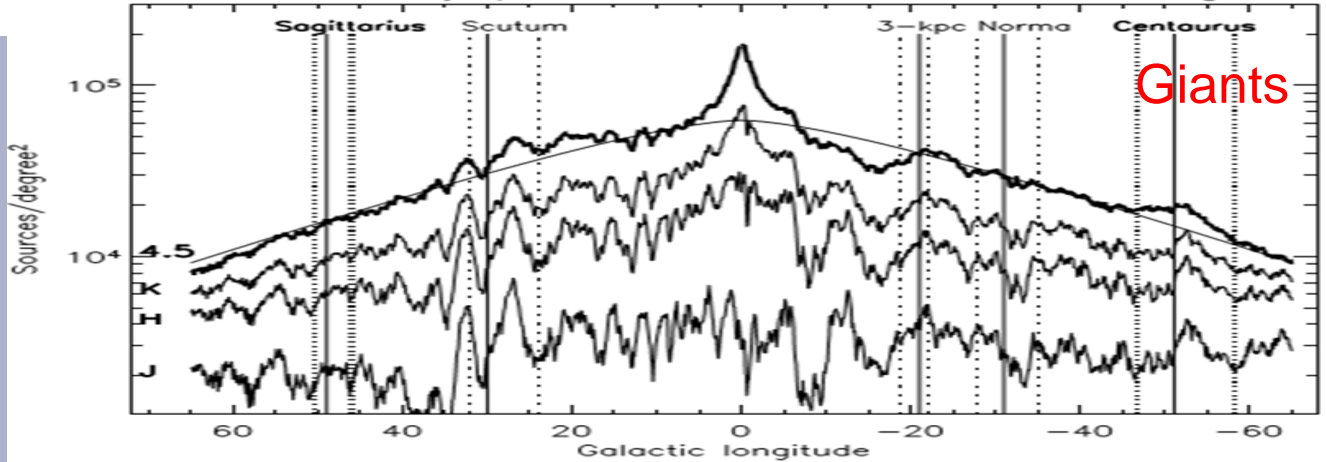
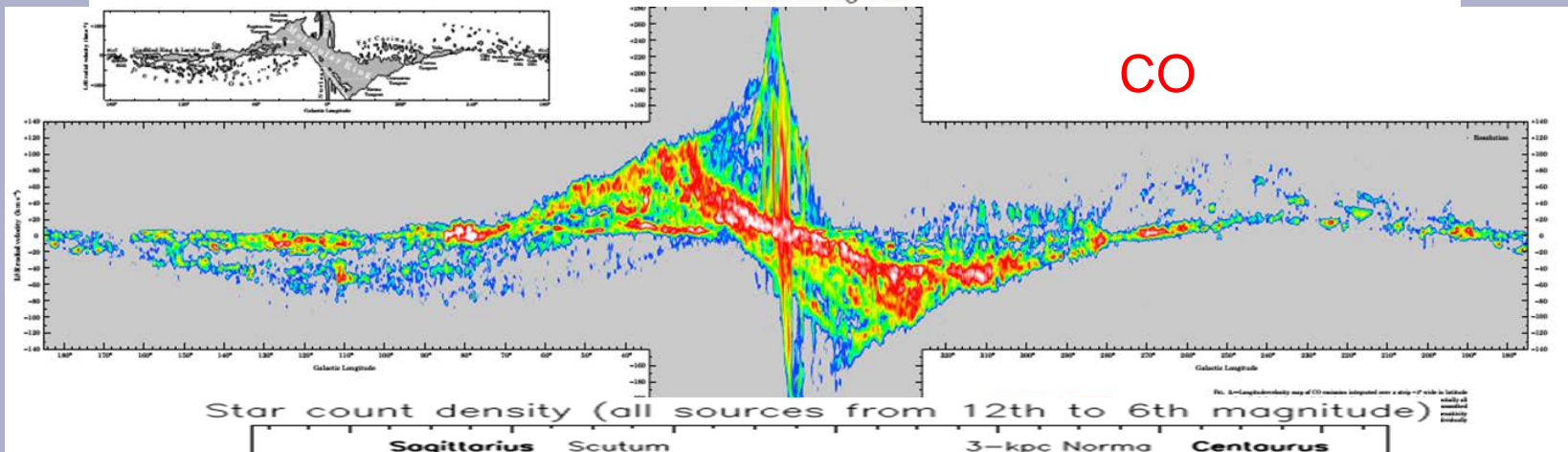
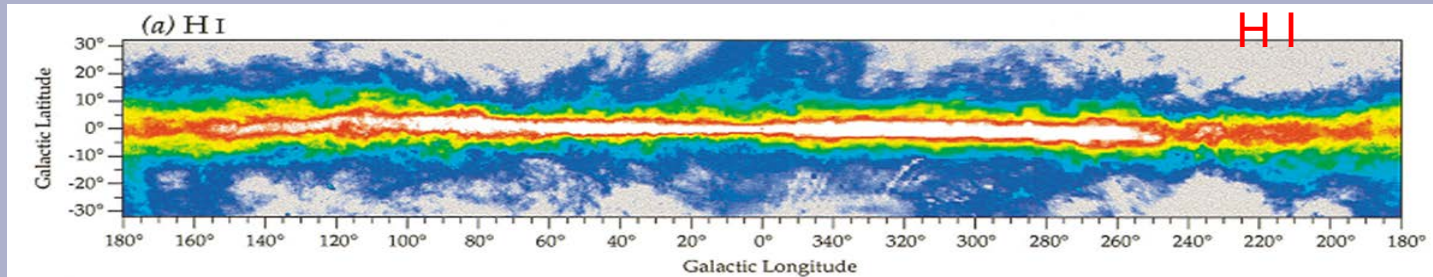


Steiman-Cameron 2010

# No Arm !



# Large-scale structures



Giants

# Large distance uncertainty

➤ Difficulties in determining an accurate rotation curve

➤ Non-Circular Rotation

➤ Kinematic Distance Ambiguity

G9.62+0.20:

far kinematic dist.	15 kpc
near	0.5 kpc
Parallax Distance	5.7 kpc

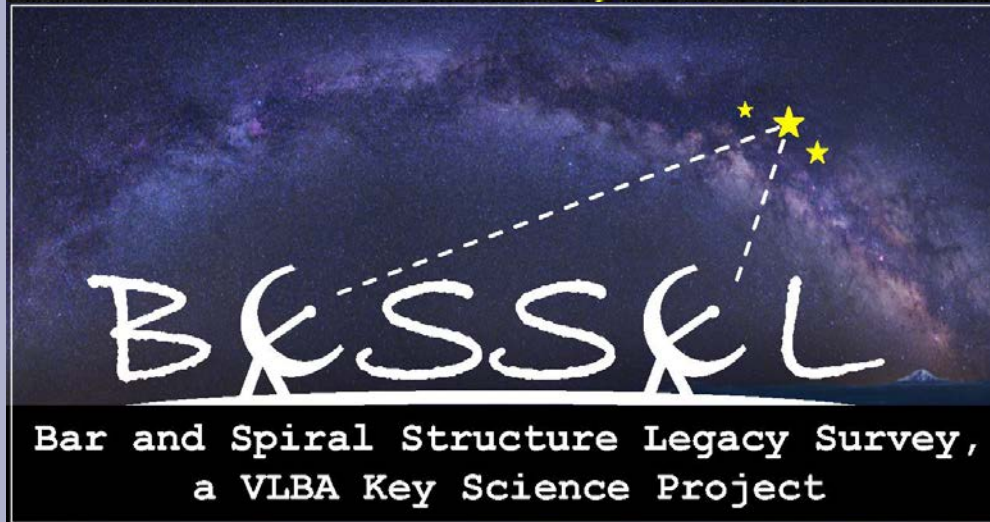
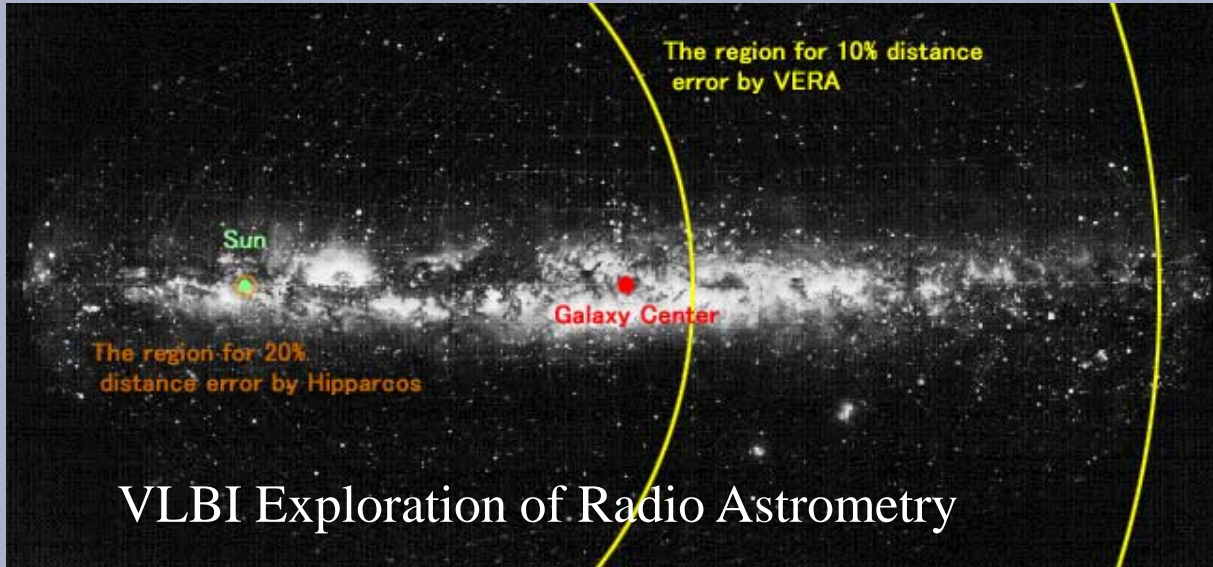
➤ Kinematically anomalous

W3OH:

Kinematic Distance ~ 4.3 kpc

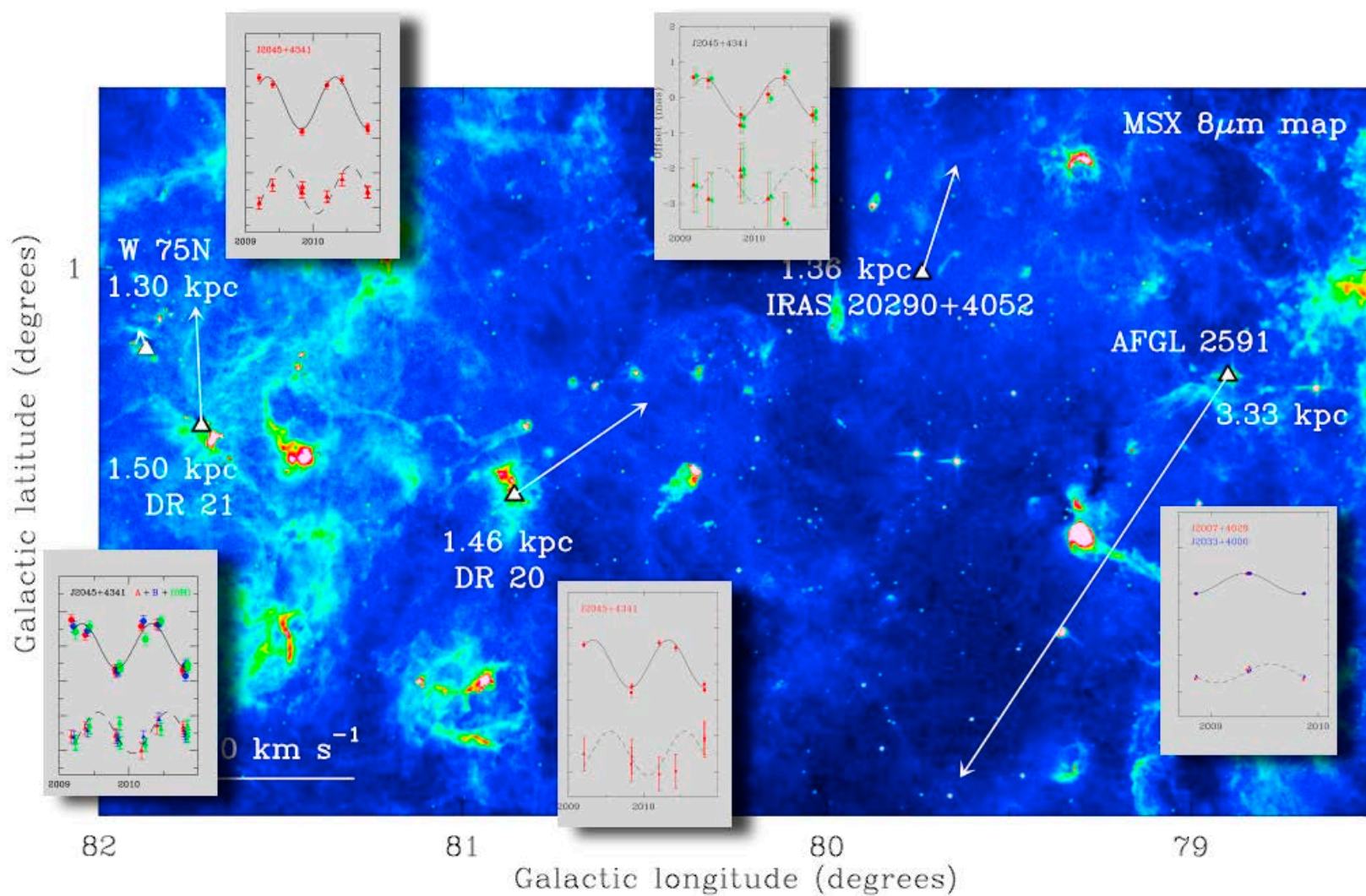
Parallax Distance ~ 2.0 kpc

# The VERA & BeSSeL Survey



- ~ 1000 masers
- will yield accurate distances to most HMSFR, locate the spiral arms and the bar, measure  $R_0$  and  $\Theta_0$  to ~1%, and measure the rotation curve.

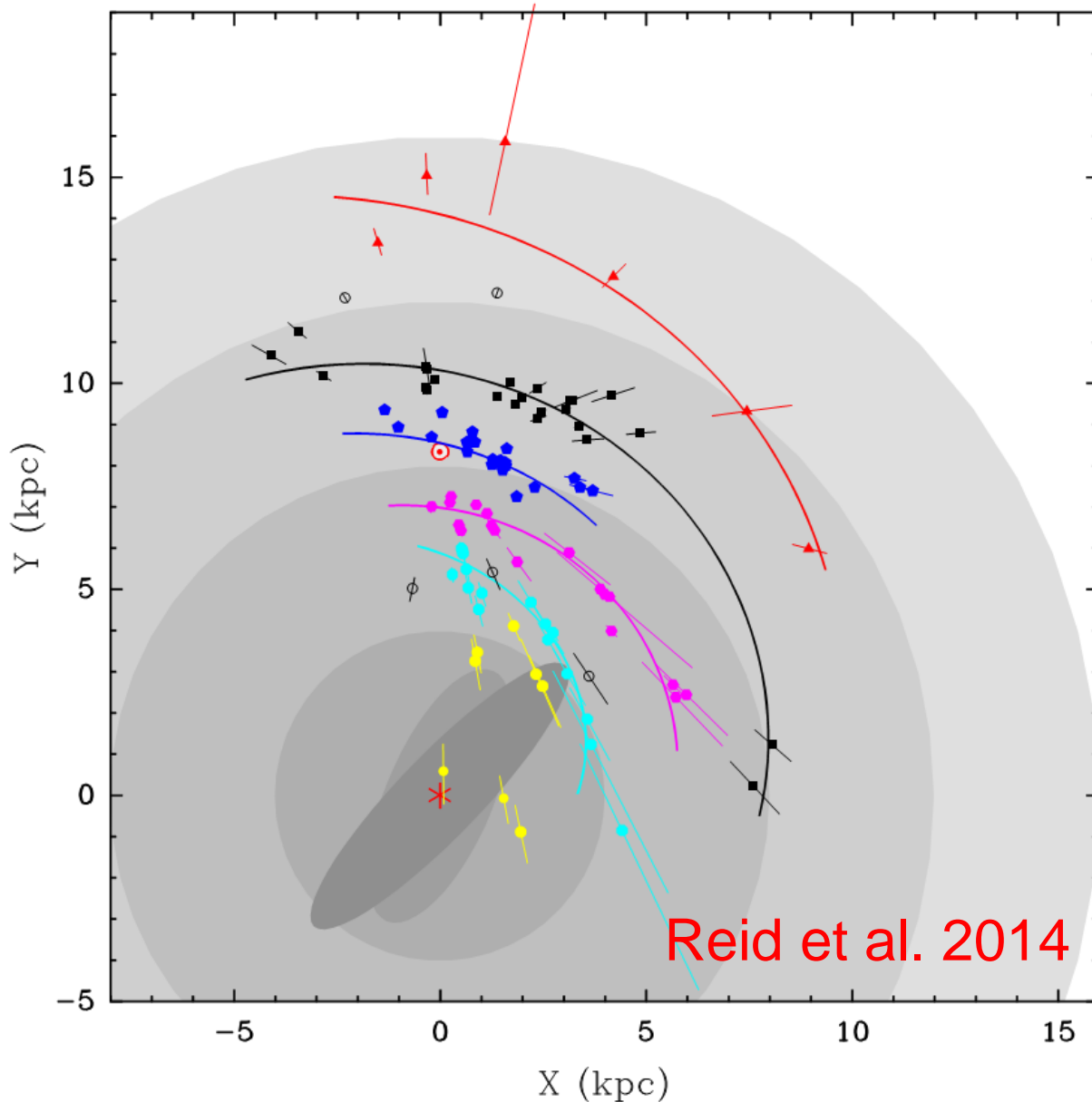
# Cygnus X Star forming complex (Masers)



Rygl et al. (2012)

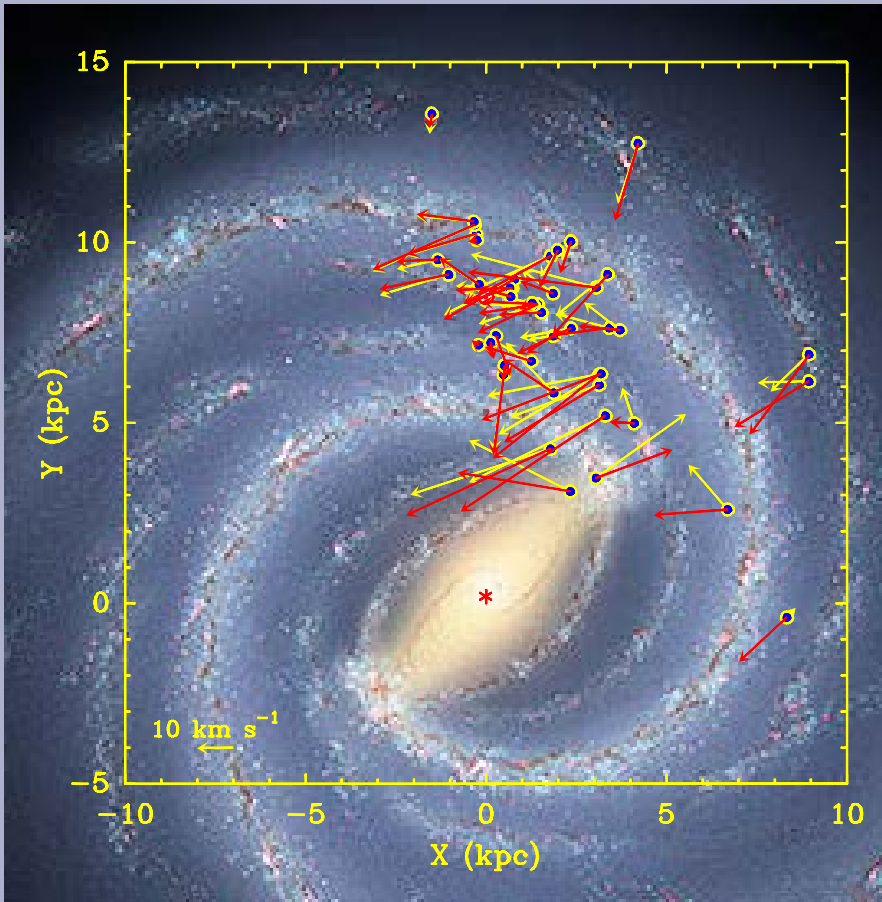


# All parallax results



- Results of parallaxes from VLBA, VERA & EVN:
- ~ 100 sources
- Strong evidence for spiral arms
- Inner, bar-region & outer arm  $\Rightarrow$  large uncertainty

# Counter-Rotation of Star Forming Regions



Compute Galactic-centric  $V$   
Transform to frame rotating at  
 $\Theta_0 = 245 \text{ km/s}$  (**yellow**)  
See peculiar (non-circular)  
motions ...clear counter-rotation

Transform to frame rotating at  
 $\Theta_0 = 220 \text{ km/s}$  (**red**)  
Still counter-rotating

But is sensitive to Solar Motion...

# Change on Solar motion

- Until 2009, the Dehnen & Binney (1998) HIPPARCOS Solar motion of

$U_0 = 10.00 \pm 0.36$  km/s (radially inwards),

$V_0 = 5.25 \pm 0.62$  km/s (in the direction of Galactic rotation),

$W_0 = 7.17 \pm 0.38$  km/s (vertically upwards)

was widely accepted.

- After part of parallax results published, HIPPARCOS revised: Schoenrich, Binney & Dehnen (2010)

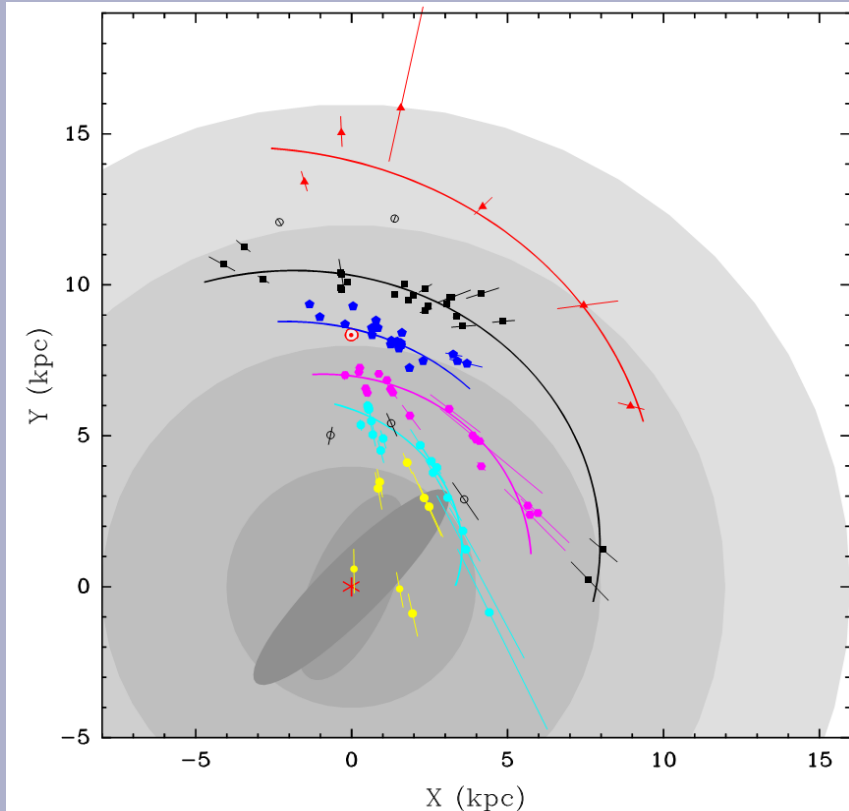
$U_0 = 11.1 \pm 2.0$  km/s,

$V_0 = 12.2 \pm 2.1$  km/s,

$W_0 = 7.2 \pm 2.0$  km/s

**NEW :  $V_0 = 14.6 \pm 5.0$  km/s (Reid et al. 2014)**

# Large distance uncertainty



⇒ in-beam calibrators

Systematic errors  $\propto$  angular separation

i.e., W3OH:  $0.5 \pm 0.010$  mas ( $0.8^\circ$ )

$0.5 \pm 0.017$  mas ( $1.5^\circ$ )

## 1. SNR/Sensitivity :

Masers: flux density threshold for phase-ref

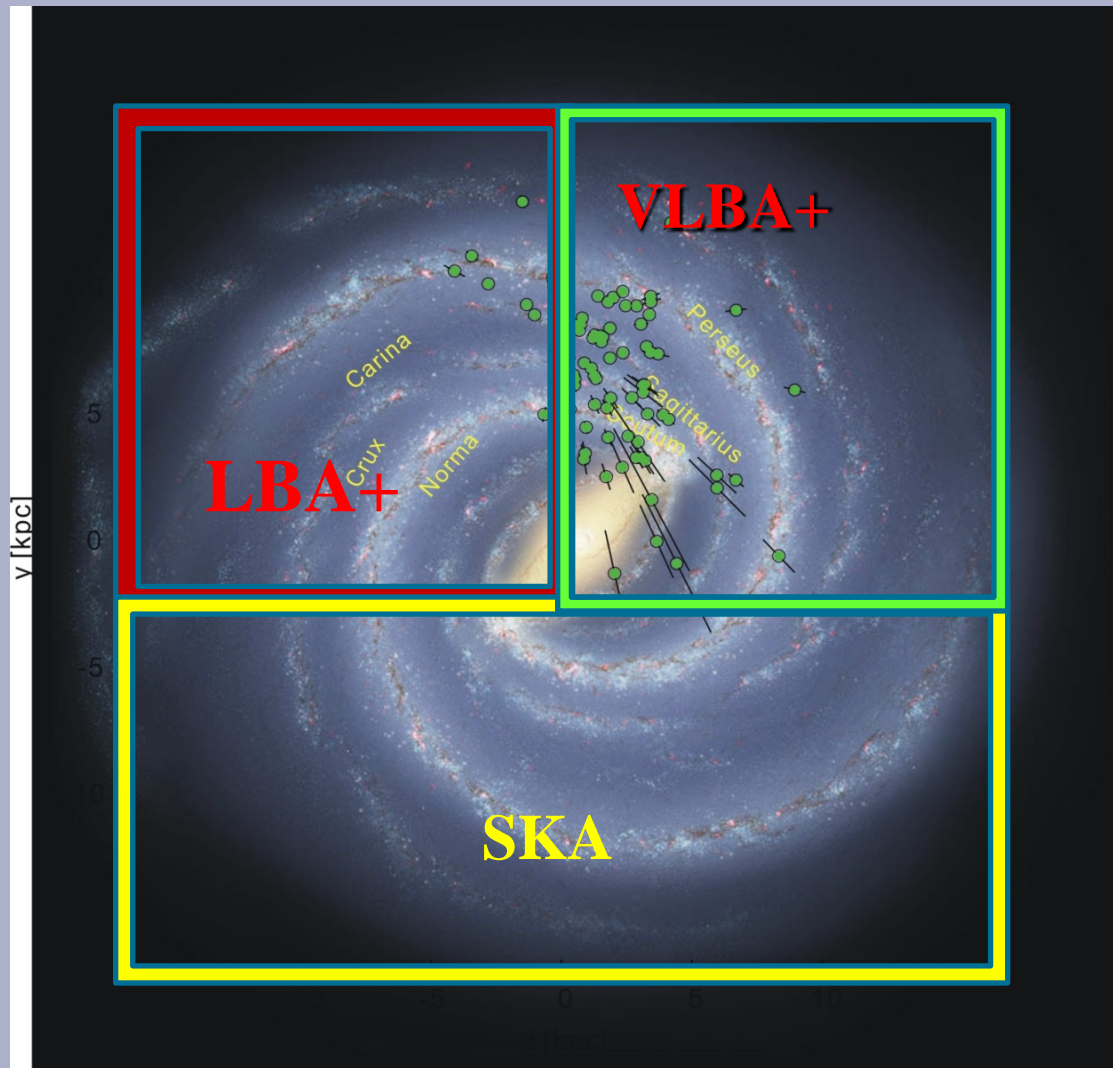
5 Jy for 22 GHz H<sub>2</sub>O & 12.2 GHz CH<sub>3</sub>OH  $\sim$ 200/2000

2 Jy for 6.7 GHz CH<sub>3</sub>OH 400/2000

## 2. Weak station geometry in Southern hemisphere

→ Large field of view or/and sensitivity

# Now & Future



# Future VLBI Astrometry ---- SKA

large field of view & sensitivity

- **Target sources**

Masers: 1000 → 6000;

- **Calibrators**

QSOs:  $10^4 \rightarrow 10^6$

- **Accuracy**

Several in-beam calibrators

Systematic errors greatly reduced

Parallaxes of ~ **1  $\mu\text{as}$**



# Conclusions

- VLBA, VERA & EVN parallaxes to young stars tracing spiral structure of MW
- Star forming regions “counter-rotate” by  $\sim 5$  km/s
- SKA will construct the accurate the spiral structure of MW finally